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Investigation of profiles of vertical velocity skewness and the source of layers of positive Skewness as measured by Doppler lidar during COPS

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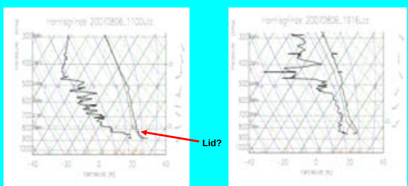
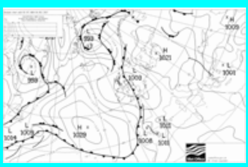
Location

Doppler lidar, radiometer and AWS based at Supersite R, Achern (see map for location).

Doppler lidar can measure wind velocity and relative backscatter co-efficient. For reference, the Hornisgrinde is in the background



The 6th August was selected after examination of the vertical velocity timeseries measured using Doppler lidar for that day showed what seemed to be a straightforward case of convective rainfall. The synoptic chart for this day didn't show any features to suggest otherwise. To confirm this, radiosonde data was examined and a convective boundary layer was present.



From the radiosondes, it is possible to see convective conditions earlier, with stable, moist conditions later in the day. This is consistent with the passing of a rainfall event. An arrow indicates an inversion which seems to act as a 'lid' on the convection.

Skewness

- Skewness is a measure of asymmetry in distribution of vertical velocity perturbations
- Positive skewness at the surface suggests narrow, intense updraftsfrom the surface and broad downdrafts – i.e.: fair weather, clear
- Negative skewness suggests sharp, narrow downdrafts and larger areas of weaker updraft i.e.: cloudy day

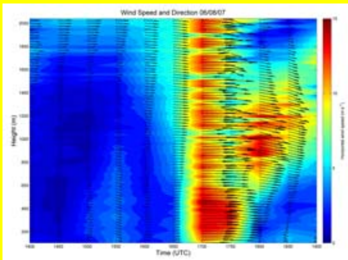
Skewness has been calculated using this equation:

$$S = \overline{w'^3} / \left(\overline{w'^2}\right)^{3/2}$$

Since the Salford University Doppler lidar is capable of measuring vertical velocity it is considered an ideal instrument for measuring profiles of vertical velocity skewness throughout the boundary layer. Knowing the skewness can help[understand the structure of turbulent convection within the boundary layer.

The horizontal velocities measured by the lidar (below) for the 6th August revealed light, winds in the morning, becoming stronger and westerly in the afternoon. At around 1700, the lidar measured a sharp increase in wind velocity, rainfall was first measured by the Salford University AWS at Achern at 1730 UTC and persisted for half an hour.

The vertical velocities measured by the lidar reflect this with convective plumes visible, progressively growing and resulting in a strong updraft followed by the strong downdraft associated with the rainfall.



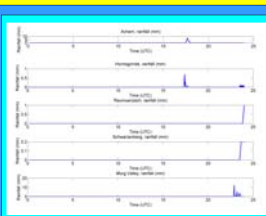
Climatology of convective rainfall days

The Convective and Orographicaly-Induced Precipitation Study (COPS) field trial was conducted in the Black Forest region of Germany during the summer of 2007. Its aim was to advance the quality of forecasts of orographically-induced convective precipitation using extensive observations and modelling (COPS, 2007). As part of this study, the Salford University UFAM Doppler Lidar, Radiometer and AWS were deployed in the COPS region, at the Achern site. All instruments were set to run continuously from the 13th June to the 16th August 2007.

One aim was to produce a brief climatology for convective rainfall events, with wind speed, direction and onset of rainfall, using the Salford University instruments. This has been compared this with other instruments and WRF data on one such day, in this case, the 6th August 2007 (COPS IOP 14a).

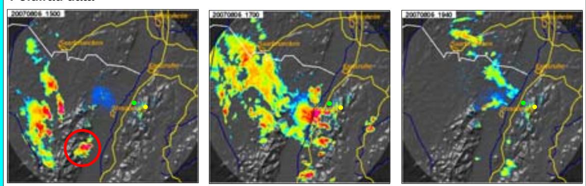
The days selected for the climatology were characterised by low wind speeds and rainfall in the afternoon. The table below shows the average wind speed and direction with the average time for onset of rainfall on convective days.

Mean wind speed (m s^{-1})	3
Mean wind direction (°)	203
Mean onset time (UTC)	1650



The raingauge network recorded the first rainfall on Hornisgrinde at 1700 UTC, then Achern at 1730, with rainfall then recorded at the Murg, Schwarzenberg and Raumenzach sites respectively, later on at around 2300 UTC. Since the prevailing wind was westerly, it was expected that the rain would reach Achern, then Hornisgrinde, Raumuenzach, Schwarzenberg and finally the Murg site, however it is considered that the orography caused a funnelling effect and triggered a secondary rainfall event.

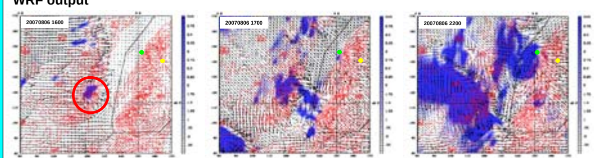
Poldirad data

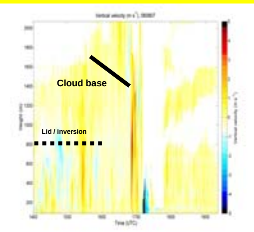


The rainfall event was investigated further by looking at data from the C-band Poldirad of DLR which was located near to Strasbourg (Location map) and output from the WRF model showing wind vectors and precipitation.

The Poldirad data shows a storm triggered in the Vosges mountains (highlighted with a red circle), intensifying across the Rhine Valley to the south west of Achern, and moving north and east to reach Achern at approximately 1700 UTC. The WRF output suggests rain triggered in the same place (again, highlighted with a red circle), but an hour later. It reaches just west of the Achern area at around 2000 UTC and becomes widespread by 2200 UTC. The Achern and Hornisgrinde sites are marked with a green and yellow dot respectively.

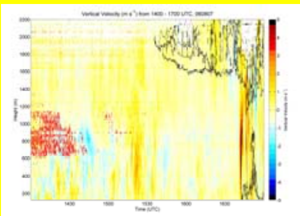
WRF output

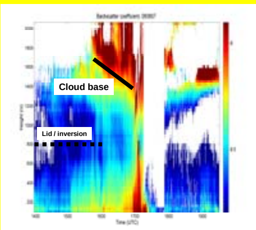




Thermals develop throughout the afternoon (left and right), but appear to be suppressed at around 800 m by an inversion / lid, which appears as a layer of very clear air (low beta), shown with red contours and is also marked on the earlier radiosonde (above). At around 1515 UTC it is possible to see a vigorous thermal which appears to break through the inversion.

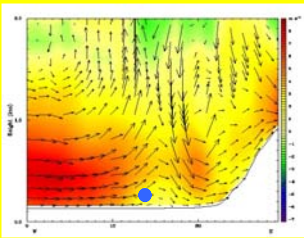
WRF output (centre right) also shows a cross section of a strong updraft, at the later time of 2000 UTC. In the figure, Achern's position is marked by a blue dot.

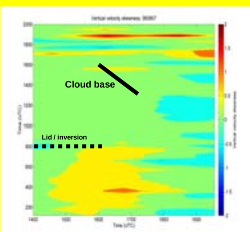




The cloud base on all the figures (left) is marked by a black line and is marked on the figure (top right) by black contours. It is possible to see the cloud base lowering just before the onset of rain.

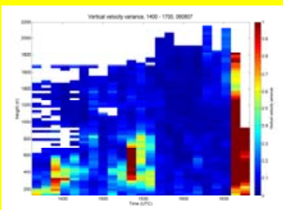
The figure (bottom right) shows vertical velocity variance measured by the Doppler lidar. It is possible to see the turbulence that represents 2 smaller thermals at 1430 and 1500 UTC and the strong updraft that preceeds the rainfall.





The vertical velocity skewness figure (bottom left) shows the themals as positive skewness 'trapped' under the inversion, which is broken down by the rainfall event. It is possible to see the strong updraft preceeding the rain at 1700 UTC and the downward movement associated with the rainfall.

The thinner layers of positive and negative skewness at around 1800 – 2000 m are thought to be cloud layers.



Conclusions:

- Measurements of skewness profiles through the boundary layer are not well documented but can be measured using Doppler lidar
- The rainfall event on 060807 was observed by the COPS raingauge network and DLR's C-band Poldirad radar.
- The precursors and after-effects of the rainfall event on the windflow were recorded by the Salford University Doppler lidar.
- Convection on this day is thought to have been suppressed by a 'lid', which could be observed in the radiosonde data, and its presence suggested by Doppler lidar observations of vertical velocity skewness.
- WRF output showed wind direction consistent with that measured by the lidar
- WRF and Poldirad show a rainfall cell initiate over the Vosges mountains
- WRF output showed convection and the onset of widespread rain over the COPS area following a strong updraft
- The WRF output showed onset of rainfall near Achern at 2000 UTC, then more widespread rainfall at 2200 UTC

Acknowledgements:
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